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MANAGEMENT OF NATURAL RESOURCES
THROUGH
AUTOMATIC CARTOGRAPHIC INVENTORY

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15. Abstract : Significant results of the ARNICA program (February - December 1973) a) The qualitative processing of ERTS data was developed along 2 lines : - the study of geological structures and lineaments of spanish Catalo- nia - the phytogeographical study of the forest region of the Landes of Gascony (France) In both cases it is shown that the ERTS imagery can be used in esta- blishing zonings of equal quantitative interpretation value. b) In keeping with the operational transfer program proposed in previous re- ports between exploration of the imagery and charting of the object, a precise data processing method was developed, concerning more particu- larly the selection of digital equidensity samples computer display and rigorous referencing.		

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PART I

PREFACE

- OBJECTIVES
- SCOPE OF ACTIVITY
- SIGNIFICANT RESULTS
- CONCLUSIONS

OBJECTIVES

In keeping with the research plan proposed in the previous reports, the processing of ERTS imagery has been carried out along 2 basic lines :

- . Two-fold qualitative studies
 - to evaluate the level of correlation between knowledge acquired from ground truth (vegetation or geology) and satellite imagery.
 - to derive laws of correspondence for use on ERTS imagery in conjunction knowledge about natural resources on poorly known or unknown sites.
- . Quantitative studies for coordinating the qualitative processing of the imagery with the automatic restitution of data on inventory and evolution of major types of natural resources.

Thus this report is concerned with methodology.

SCOPE OF ACTIVITY

- The qualitative studies concentrate on basic themes :
 - geological, using as test-site the northeastern region of spanish Catalonia, where stratigraphy and tectonics are presently well known, notably from the work of B. DONVILLE.
 - phytogeographical, selecting the Landes of Gascony area for its particularly favorable conditions for studying methodology relating to models of forestry and agriculture.
- The quantitative studies, completing the results already obtained, involve the following problems :
 - computer display techniques after microdensitometer treatment of the imagery
 - development of high precision methods for referencing imagery information
 - coordination of successive sampling operations required for feasible automatic data processing.

SIGNIFICANT RESULTS

A. QUALITATIVE STUDIES

see Part II, Chapters 1 and 2

1. Data 1115-10033 MSS 4, 5, 6, 7 (Geology)

ERTS imagery was compared with known geological structures in Catalonia, which prove to be particularly complex : the "brittle tectonics" of the region shows up perfectly on the satellite imagery and the 3 main lineament directions (NE-SW ; NW-SE ; NS) are confirmed.

This example clearly shows that a preliminary interpretation of ERTS imagery would have greatly facilitated the very complex ground studies that have been carried out in this region for many years.

2. Data 1064-10190 MSS 4, 5, 6, 7 (Phytogeography)

The great forest area of the Landes of Gascony lends itself particularly well to a "photozoning" interpretation of the ERTS imagery as well as to a comparizon with the "cartozoning" derived from the vegetation maps.

The forestry landscapes are closely tied to the geomorphology of the land and to drainage conditions assured by the hydrographical network on essentially sandy soil. There is therefore a very useful correlation between "densitometric ensembles" revealed by the imagery and phytogeographical ensembles actually present on the ground.

SIGNIFICANTS RESULTS (continued)

Furthermore the mixture of deciduous-conifer which characterizes the forestry distribution is perfectly shown by comparizons of MSS 5 and 7 data, as are the major zones of intensive irrigated corn cultivation.

This break down of the imagery into zones of equal value has been studied quantitatively and the results confirm its limits and its interest.

SIGNIFICANT RESULTS (continued)

B. QUANTITATIVE STUDIES

see Part II, Chapters 3 à 5

Data 1027-10135 MSS 4, 5, 6, 7

1. (Chapter 3)

The first series of operations to be carried out after microdensitometric treatment of the imagery (cf. Type II Progress Report n° 1, chapter 3) consists of obtaining a good visual restitution of the image using a printer.

This display can be obtained by means of either graphical symbols giving a visual impression like the original, or numerical values which give the optical density of each point.

Such restitution, applied to the entire image, or to partial zones preselected for their qualitative value, involves the following stages :

- 1 - Calculation and transformation of data
 - . decoding of information
 - . calculation of integral optical density in the test zone under consideration
 - . calculation of density frequency histograms
 - . calculation of statistical distribution characteristics
- 2 - Automatic data restitution
 - . numerical output
 - . printout

Testing and development were conducted jointly on ERTS documents, on a very small scale, and on imagery taken from stratospheric balloons on a larger scale. This assures a good relay of information between known land features and remote sensing data.

SIGNIFICANT RESULTS (continued)

2. (Chapter 4)

One absolutely indispensable condition for accurate treatment lies in the absolute rigorous referencing of the samples on ERTS imagery. The precision detection by microdensitometer (25μ steps) is only usable if the mechanical selection of test-zones can be insured with an equal degree of accuracy.

The method developed is based on :

- 1° the automatic referencing of 4 reference crosses at the 4 corners of the original ERTS document (referencing is facilitated by microdensitometric analysis of the microscopic pinholes punched manually in the center of each cross directly on the film).
- 2° transposition of the reference system : a sample defined in the reference system formed by the crosses on the ERTS image can thus be referenced very accurately with respect to the microdensitometer digitalization axes by translating and rotating the axes.

SIGNIFICANT RESULTS (end)

3. (Chapter 5)

The third stage of the chain of transfer operations consists of selecting successive of digital equidensity levels on the test-site, which indicate ground truth to be analyzed.

The following stages of work are involved :

- . "Qualitative" selection of the test-site by means of "cartozoning - photozoning" comparison and identification on the ERTS image.
- . Processing the sample by means of a FORTRAN program and the establishment of density histograms.
- . "Filtering" of the information and break down of the general histogram into the most significant major density levels.
- . Display of the entire test-site after coded information compression according to the levels retained.
- . "Qualitative" preselection of new more homogeneous samples of different soil occupation types, in parts of the image where the correlation between spectral response and ground truth seems most satisfactory.
- . Statistical treatment of the homogeneous samples in the 4 ERTS bands and numerical and graphical detection of the best decoding combinations for each ground truth.

Results show the primary interest of comparing MSS 5 and MSS 7, which proves to be the best for class discrimination. Recourse to MSS 4 and MSS 6 information is necessary only in subsequent operations to avoid possible ambiguities.

CONCLUSIONS

The studies presented in this report show feasibility of the main stages in the chain of transfer operations from ERTS imagery to automatic cartography.

The general feasibility of one example of transfer has been shown in the last report. Here it is necessary to specify in detail certain stages of the program :

- . selection of qualitative data
- . sampling problems
- . rigorousness of experimentation

The methods proposed here should be useful in other fields as will be shown in the next definitive report on the ARNICA program.

PART II

RESULTS

Chapter 1. QUALITATIVE STUDIES : Geology

- ERTS 1 SATELLITE DOCUMENTS AND GEOLOGICAL STRUCTURES OF NORTH-EAST OF CATALONIA

by B. DONVILLE, Department of Geology and Geomorphology, Université Paul Sabatier

Chapter 2. QUALITATIVE STUDIES : Phytogeography

- IDENTIFICATION OF LANDSCAPE TYPES FROM ERTS 1 IMAGERY (Landes de Gasconne - France)

by Mme P. GOUAUX, Department of Teledetection, Université Paul Sabatier and D. LOUBET, Centre d'Etudes Spatiales des Rayonnements

Chapter 3. QUANTITATIVE STUDIES

- DISPLAY PROBLEMS

by Mme T. LE TOAN and M. MONCHANT, Centre d'Etudes Spatiales des Rayonnements

Chapter 4. QUANTITATIVE STUDIES

- METHOD FOR LOCATING SAMPLES ON ERTS IMAGERY

by Mme T. LE TOAN, J.C. GUYADER, Centre d'Etudes Spatiales des Rayonnements and Mme P. GOUAUX, Université P. Sabatier

Chapter 5. QUANTITATIVE STUDIES

- RESPONSES OF DIFFERENT TYPES OF SOIL OCCUPATION DEFINED FROM HOMOGENEOUS SAMPLES

by Mme T. LE TOAN, J.C. GUYADER, M. MONCHANT, Centre d'Etudes Spatiales des Rayonnements

Chapter 1.

ERTS SATELLITE DOCUMENTS
(1115-10033 MSS 4, 5, 6, 7.)
AND GEOLOGICAL STRUCTURES
OF NORTHEAST OF CATALONIA
(Spain)

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ERTS 1 SATELLITE DOCUMENTS 1115,
1033 MSS 4, 5, 6, 7 and
GEOLOGICAL STRUCTURES OF NORTHEAST CATALONIA

- B. DONVILLE -

We shall briefly review the geological composition of the northeastern part of Catalonia. We shall consider only the region limited on the north by the French border, on the west by the eastern end of the Ebre basin, on the south by the southern boundary of the Montseny mountain range and on the east by the Mediterranean. In this zone mainly the following units are found (figures 1 and 2) :

- The eastern part of the axial zone of the Pyrenees, composed mainly of palaeozoic and cristallophylian materials (1, 2, 3).

- The eastern part of the sub-Pyrenean zone, characterized by eocene formations with rather intense crumpling (4).

- The Transversal Catalan system, composed of eocene formations in particular the block of Cabrerres, the graben of Olot and the horst of the Garrotxa.

- The Ampurdan depression, in which primarily continental formations of the Neogene and Quaternary overlap the intensely folded and faulted Eocene (5).

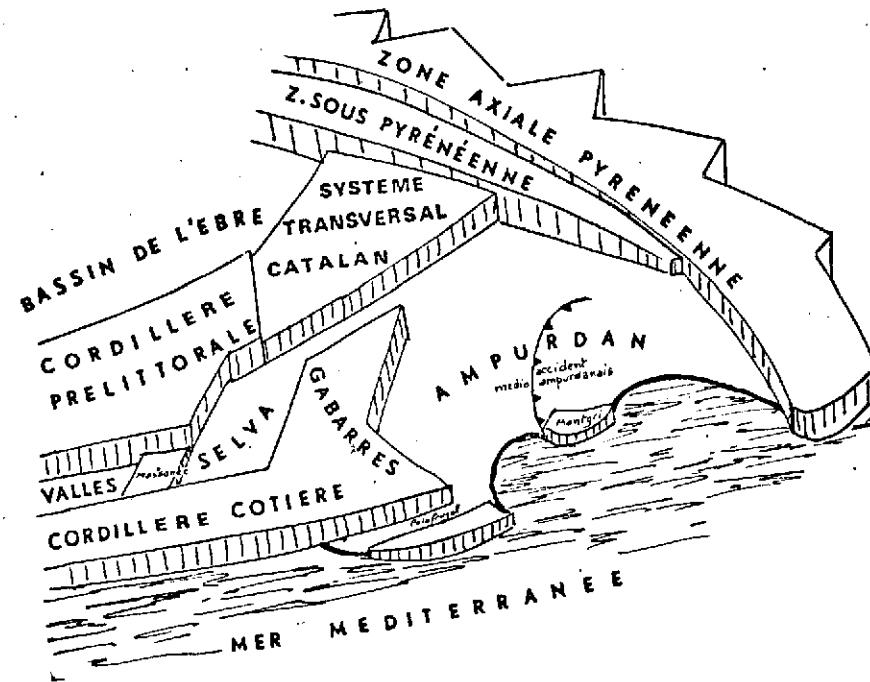
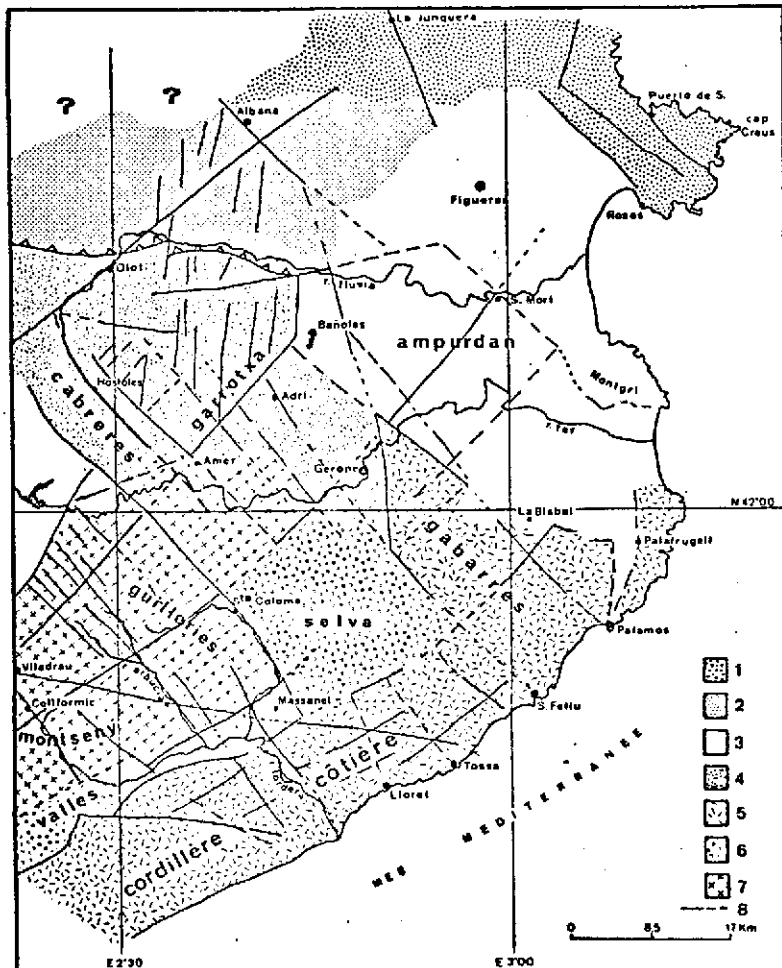


Figure 1



SCHFPA STRUCTURAL DU NE DE LA CATALOGNE.

1-Zone axiale pyrénéenne. 2-Zone sous-pyrénéenne. 3-Ampurdan.
4-Système Transversal Catalan. 5-Cordillère cotière catalane.
6-Dépression pré-littorale. 7-Cordillère pré-littorale.
8-Principaux "linéaments" carsants.

Figure 2

- The western part of the Catalanides, composed of the coastal cordillera including the Gabarres mountain range formed by palaeozoic and granitic areas, prelittoral depression (Valles, Selva) filled by continental ponto-plio-quaternary sediments and the prelittoral cordillera formed essentially by palaeozoic and granitic areas (6).

The structural data above can be found in and supplemented by documents 1115 10033 MSS 4,5,6,7, because of the brittle character of the substratum of this region accentuated by many lineaments (7). Figure 3 reproduces the MSS 6 document on a larger scale and emphasizes these lineaments.

If only those lineaments which seem to correspond to fractures are considered, certain general observations can be made (8) :

- With rare exceptions there are only 3 main directions : NE-SW ; NW-SE ; N-S.

- Possible N-S aligned fractures do not seem to be found systematically outside the Garrotxa and the sub-Pyrenean zone.

- The NE-SW Catalan direction, whose importance has already been pointed out on the French side of the axial zone, seems to play an important role, even outside of the Catalanides.

When possible, we shall analyse the observational results of these images for each of the previously defined structural units.

1. Pyrenean axial zone (Zone axiale pyrénéenne)

As we see in figure 2 all observations have been obscured by cloud formations, in the N and NW. Nevertheless, in the Alberes region one can notice that the preferential direction of the major lineaments is NW-SE. From E to W the following are identifiable :



Figure 3

- the Puerto de la Selva fault (NW-SE) ;
- the bordering fault of the Ampurdan passing by Rosas (NW-SE) ;
- the great Junquera fault (NNW-SSE).

2. Sub-Pyrenean zone (Zone sous-pyrénéenne)

This zone is also usually covered with clouds. However one can recognize the great Albaña fault (NW-SE) which starts in the axial zone. It seems to reappear in the Ampurdan after curving inward (NNW-SSE) and further south follows the western edge of the Gabarres mountain range. Further west a set of N-S lineaments is situated north of the overlapping line separating this zone from the Garrotxa, a line which is barely visible on the image because it is parallel to the principal alignments of the eocene structures. In addition, let us point out the penetration of the great Olot fault into this zone, described in the following section.

3. Transversal Catalan System (Système transversal Catalan)

There is a great fault from NE-SW passing through Olot and penetrating deep into the sub-Pyrenean, even cutting into the Albaña fault. The existence of this fault has already been stressed by CHEVALLIER and can be found in the works of MARCET RIBA (4 ; p. 94). But on the latest maps, particularly the Figueras geologic map (scale 1 : 200,000) (1) it is not shown at all.

To the east of this fault the southern limit of the Garrotxa seems to correspond, in the southwest to the Hostoles fault (NW-SE) and, in the east, to a fault NE-SW, less apparent, which apparently goes through lake Bañolas. These two fractures seem to be southern limits for many of the N-S accidents observable in the horst of the Garrotxa.

These accidents cut back the directions of the EW lineaments corresponding to the main eocene structures of this zone (not shown on Figure 1).

It must be pointed out that in this same zone is a slightly E-W lineament which could correspond to a fracture whose extension may be found in the Ampurdan.

The eastern border of the horst of the Garrotxa may then correspond to a fracture belonging to the N-S system which passes west of lake Banolas.

4. The Ampurdan (L'Ampurdan)

Buried beneath neogene and quaternary, often argillaceous formations, the brittle structures of the Ampurdan are usually difficult to see. However certain lineaments with directions mainly NW-SE and NE-SW can be seen. Thus such a line (NW-SE) beginning at Montgri and passing near San Mori must correspond to the deep accident locally indicated by evidence of Cretacian overlying Eocene.

In addition, a long lineament directed NE-SW seems to be found in the entire Ampurdan. It may not correspond to any known structure or fault. It nevertheless seems important since, its extension is found along to the north of Gerone in the Catalanides mountain range ; it crosses the Montseny range and reappears north of Barcelona (8). It would seem to indicate the presence of another deep accident noticeable perpendicular to the first (NW-SE) and very wide. To the NE of the depression, the Gerone-San Mori alignment is seen to pass through Puerto de Selva. It is not inconceivable to admit its existence in the axial Pyrenean zone where it could have played a certain role in cutting out the great Cap Creus-Rosas peninsula.

In the western part of the depression, outside the fault bordering the Garrotxa (N-S), one can recognize the southern extension of the great Albaña fault. To the east of lake Bañolas it seems to branch off : there it gives rise to a NW-SE lineament which passes near La Bisbal (although showing of course no evidence on the ground) and also it extends southward.

5. The coastal cordillera (Cordillère côtière)

The Palafrugell corridor, which may constitute evidence of the shoreline depression, is limited by N-S faults. Everywhere else the main lineament direction of this cordillera is NE-SW which is also the direction of the coast.

It must be pointed out that, contrary to previously expressed ideas, the Gabarres mountain range seems to form a particular structure and the fact that it belong to the Catalanides is not apparent from these images. In fact, it seems that the NW-SE fault serves as a contact with the Ampurdan, to the west of La Bisbal, extends, to the southeast, toward Palamos, and thus specifies to the Northeast of the range, a part wedged between the graben of Palafrugell and the extension of the great southern bordering fault of the prelittoral depression. The western limit of the Gabarres, as we have already shown, seems to correspond to the extension of the great Albaña fault towards the south. This limit represents the southernmost manifestation of the N-S direction of fracture systems in the region. The Albaña fault runs into a NW-SE fault passing perceptibly to Canet d'Adri and crossing the coastal cordillera toward the southeast to San Feliu de Guixols. Furthermore the Gabarres mountain range seems fractioned by the extension of the great southern Valles fault (NE-SW) which limits the coastal cordillera towards the NW.

The preferential direction (NE-SW) can further be seen in a certain number of alignments within the range, and is like that of many veins of porphyric rocks found there.

This structure lying NE-SW is cut off perpendicularly by several NW-SE fractures, mainly that of the Rio Tordera, the Lloret de Mar and the Tossa de Mar.

In addition, towards the southern part of the zone under study, one notices the presence of two E-W, very wide lineaments. The first, crossing the threshold of Massanet, penetrates deep into the prelittoral cordillera, where it forms the western limit of the Montseny block, passing near Viladrau. The second and smaller lineament creates a transverse fault from the great southern bordering fault of the prelittoral depression.

6. The prelittoral depression (Dépression
prélittorale)

The remarks made about the Ampurdan apply here as well, namely that buried under recent clay sediment, different lineaments corresponding to fractures in the support are scarcely visible. There is only evidence of the bordering faults of the depressions and these are described in the paragraphs about other units.

7. The prelittoral cordillera (Cordillère
prélittorale)

It is in this structure that the most brittle lineaments are to be found. They belong typically to two systems of fractures oriented NE-SW and NW-SE.

Besides the extension of certain fractures of the Transversal Catalan System, the main NW-SE fault observable in the western part of the Cordillera, is the Santa Coloma de Farnes fault.

Following this same direction (NW-SE), a very large number of fractures of varying sizes, outline stepping blocks in this Cordillera, mainly the previously mentioned Santa Coloma, the Arbucias river, and the Collformic. This same orientation of fractures is found well developed in many lineaments in contact with the inner depression to the NW of the Guillerics block. The NE-SW preferential direction is accentuated by very long but fewer fractures. The main one of these appears to be composed of the extension, towards the SW, the accident, which we have named San Mori-Gerona, and what can be found to the north of Barcelona. It thus seems to divide the prelittoral cordillera longitudinally and serves as a NW limit to the La Selva depression. To the SE of this median accident, the outline of the bordering fault of the prelittoral depression is more jagged and eventually disappears where it meets the ridge of Massanet and La Selva. Conversely, towards the NW, the extension of the great accident passing near lake Bañolas, previously mentioned in connection with the Garrotxa, penetrates deep into this prelittoral cordillera.

The E-W Collformic accident which as we have seen penetrates deep into the coastal cordillera toward Tossa de Mar must be added to the two abovementioned quite perpendicular directions.

Conclusions

Outside the Pyrenean zones (the axiale zone, the sub-Pyrenean zone) the different structural groups in the NE part of Catalonia are defined by a tectonic of blocks. These are the result of a considerable fracturation but go in few directions.

Belts lying NE-SW have been created by the following great faults :

- the Olot fault
- the Bañolas fault
- the San Mori-Gerone fault
- the western fault of the Valles depression
- the western fault of the coastal cordillera.

Overlying this structure a large number of fractures, with an general NW-SE orientation, have formed different blocks which are vertically separated.

The following main fractures have such an orientation :

- the western fault of the Gabarres
- the Adri fault
- the Hostoles fault
- the Santa Coloma de Farnes fault
- the Arbucias fault
- the Collformic fault.

Thus three depressions surrounded by steps of varying heights can be identified.

- The Ampurdan, situated between the Pyrenean zone, the Garrotxa and the Gabarres mountains.

- The Selva, located between the Gabarres mountains in the NE, the Guillerics mountain ranges to the NW and SW, and for the moment including the Massanet ridge, and the coastal cordillera to the SE.

- The northeastern end of the Valles situated between the coastal and prelittoral cordilleras and locked in to the NW by the Massanet ridge.

To complete this simplified structural sketch one must add the presence of a set of N-S fractures, which seem to effect only the northern part of the zone under investigation, evidenced mainly by the extension of the Albaña fault in the south.

Finally some great E-W accidents (the Viladrau fault, for example) complete this picture apparently without influencing the previously discussed structural diagram.

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Chapter 2.

IDENTIFICATION OF LANDSCAPE
TYPES FROM ERTS-1 IMAGERY
(Landes de Gascogne, France)

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The study of the major landscape types was carried out on multispectral scanner imagery from September 25, 1972. The annotation block for this document includes the following : 1064-10190 - 01.

This image covers southwestern France. The usable part is reduced to an area well known by biogeographers : the "Landes de Gascogne" (Moors of Gascony).

I. FEATURES OF THE REGION

Situated on the maritime front of the Aquitaine, the moors of Gascony, a triangle-shaped area largely open to the ocean, forms a remarkable natural unit. The coast is planked by dunes behind which are lines of ponds ; of these only the Arcachon Basin connects with the ocean. The back country is a vast plateau of sand, 158 m high in the east, sloping down imperceptibly toward the west and the north.

In this region the landscape features can be very specifically isolated and identified. These features are included in the following areas :

- pedology : large differences in drainage ;
- geomorphology : alternating plateaux and deep narrow valleys ;
- land features : very marked development of soil occupation ; much clearing and reforestation within clear-cut geometric areas ;
- ecology : combination of pedological and climatic factors resulting in a particular vegetation pattern (forest arcades, reforested moors, cleared moors, wooded dunes, bare dunes, etc ...) ;

- history : development of the moors by means of reforestation (creation of the Landes Forest in the 19 th century) ; fires.

II. LANDSCAPE ANALYSIS

II.1. Qualitative analysis

The images show a mosaic of textures representing the various landscapes in the region.

The analysis consists of drawing a "photozoning" so that identical textures are grouped together. This operation is performed on images in MSS bands 5 and 7 which seem to be the most significant. Zones of equal texture are decoded using the zoning previously drawn up on the Vegetation Map for comparison : Bordeaux and Mont-de-Marsan sections.

Thus, after the MSS band 5 and 7 images have been studied, two photozoning are made. The photozoning for MSS 7 is the most complete.

Zone 1 : Pine forest

A homogeneous stand of pine forest (*Pinus pinaster* Sol.) on very old dunes, i.e., on intensively drained soil, divided up by a large system of fire-breaks. The land features and pedologic conditions of the soil are apparent, so that this zone can be very clearly distinguished in the two spectral bands 5 and 7.

Zone 2 :

Spectral band 7 best defines this zone by distinguishing 2 very clear sub-sets, 2 a and 2 b, not visible in spectral band 5.

2a : Forest agricultural complex

This outlines a very clear scallop around the ponds ; the points of the scallops correspond to streamside vegetation growing up to the ponds.

2b : Forestry complex

Consists of pine forestry (*Pinus pinaster* Sol.) in soil with average drainage. The texture of this area is different from that of zone 1 (pine in soil with intensive drainage). Within the wooded areas a light gray line shows the courses of streams. The response recorded at this level and in spectral band 7 is therefore not water but trees (Deciduous : *Quercus pedunculata* Ehrh.) bordering the stream and organized so that they cover and hide the course of the river in a aerial view, like the pattern of tropical "forest arcades". This feature appears often and is peculiar to the moors of Gascony.

Zone 3 :

As for zone 2, spectral band 7 best reveals, this zone. Spectral band 5 shows a coarse textured zone grouping various land features, the most frequent being the moors ; cultivated land appears on the edges of villages and along lines of communication.

Two sub-sets, 3 a and 3 b, can be distinguished in spectral band 7 :

3a : Forestry complex (*Pinus pinaster* Sol.) on well drained moorland, scattered along the course of the Great Leyre and the Little Leyre which drain a major part of the moors of Gascony. The course of the river and its affluents are emphasized by the "forest arcades" of deciduous trees (*Quercus pedunculata* Ehrh.).

3b : Heterogeneous complex of open forest, brushwood, reforesting, and cultivated land.

Zone 4 : Forestry and pasture complex

A rather poorly defined zone, in spectral bands 5 and 7, with very heterogeneous textures.

It corresponds mainly to very badly drained moorland with patches of pine woods (*Pinus pinaster* Sol.) which have grown back naturally after the serious fires of 1940 and 1947.

Zone 5 : Forest agricultural complex of Bazadais

This landscape does not belong the Landes plateau. It consists of small extents of woods (*Quercus pedunculata* Sol. and *Pinus pinaster* Ehrh.) with wide areas of cultivated land in between (primarily vineyards).

The MSS 5 image faithfully reproduces this landscape, showing the forests (dark gray) in the middle of the cultivated areas (light gray). The MSS 7 image clearly isolates this zone from the first 4 of the Landes plateau, although the difference in signature between forests and cultivated land is less clear than on the MSS 5 image.

Zone 6 : Agricultural complex on the left bank of the Garonne River.

Major vineyard zone, on stony soil, very clearly detached from the Landes plateau in spectral band 5.

Zone 7 : The Mas d'Agenais Forest

Included in zone 6, this dark gray area with very clear boundaries is clearly distinguished on spectral band 5.

It is a large forest area formed by trees with falling leaves (*Quercus pedunculata* dominating). In spectral band 7 this zone can hardly be located.

This difference between the two spectral bands brings up two points.

Two very different features are mixed in spectral band 7 :

- high formation : extensive forestry with clear outlines ;

- low formation : cultivated land.

In this case, the land features are not predominant. However, the phenological state of the formations plays an important role, so that on a spring recording (March 23, 1973), the forest was clearly distinguishable from its surroundings in the same spectral band (band 7).

Zone 8 : Swampy grassland

Swampy grassland near Bordeaux, northward, are easily located in both spectral bands 5 and 7.

Zone 9 : Urban

The city of Bordeaux clearly visible in spectral bands 5 and 7. Cities with average population density are only visible in band 7 (Langon, La Reole, Marmande, Tonneins, ...).

Zone 10 : Water

10a : Ocean water-ponds ;

10b : Waters in the tidal zone, clouded by suspensions of silt due to the continual motion of the water in both directions in the Gironde, Garonne, and Dordogne.

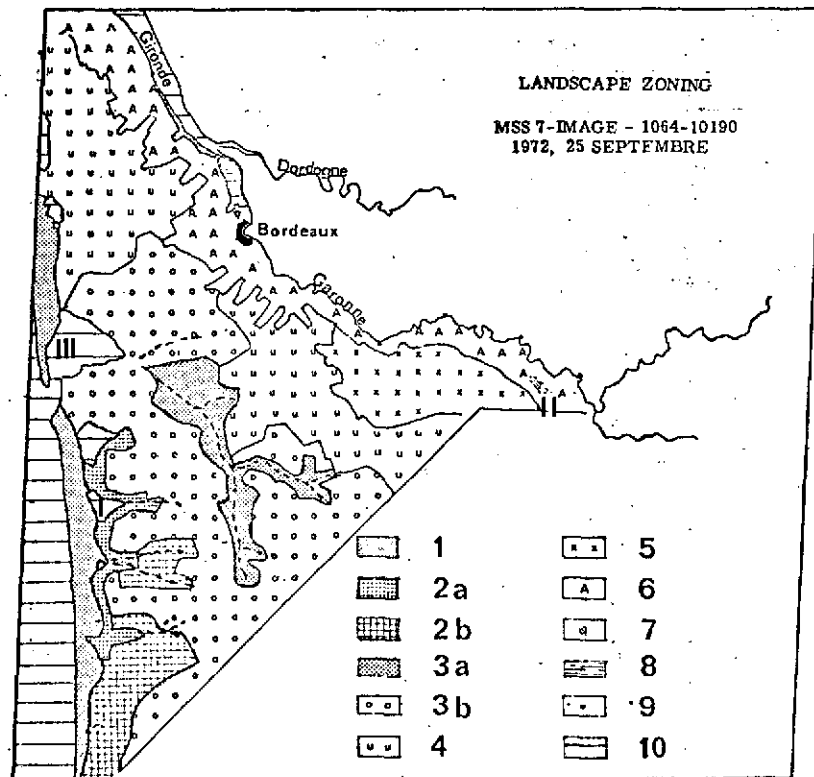


Figure 1

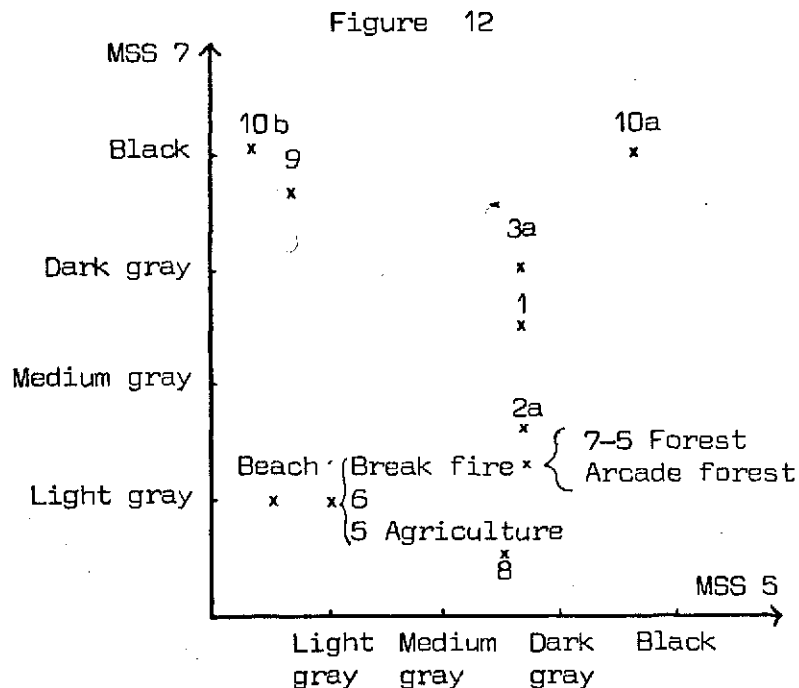
1 - Pine forest ; 2a - forest agricultural complex ; 2b - forestry complex on soil with average drainage ; 3a - forestry complex on soil with well drainage ; 3b - heterogeneous complex ; 4 - forestry and pasture complex ; 5 - forest agricultural complex of Bazadais ; 6 - agricultural complex ; 7 - deciduous forest site (hardly located in spectral band 7) ; 8 - swampy grassland ; 9 - urban ; 10 - water (ocean-ponds) ; ---- arcade forest.

I The Born region
II The Mas d'Agenais region
III The Arcachon Basin

Figure 1 represents the MSS 7 photozoning. The qualitative study allows to identify and to characterize landscapes part of landscape described by examination of 2 spectral bands.

In a spectral band, the analyzed structure is defined owing to its gray level which is the result of different teledetection factors.

The structure is, then, determined by its four spectral responses. Figure 2 indicates the responses distribution in a two-dimensional graph (MSS 5 and MSS 7).



1, 2a, 3a, 5 Agriculture, 5 Forest, 6, 7, 8, 9, 10a, 10b : landscapes.

Arcade forest, break fire, beach : part of landscape.

2b, 3b, 4 : very heterogeneous landscape not indicate.

II.2. Quantitative analysis

The zones obtained by means of qualitative analysis are used as basic data for the quantitative phase of this study. The most significant sites on the image are selected and treated quantitatively. The following test sites were chosen :

- The Born region
- The Cocumontais region
- The Arcachon Basin.

1 - The Born region

The landscapes found in the Born region are described above with determining of zones 1, 2a, 10a, (figure 3).

The data restitution corresponds to a 7 levels displays of the image, taken in spectral band 7, in which this landscape are clearly pointed out. The coding table indicates the correspondance between levels of density and landscapes.

CODING TABLE : MSS 7

60 - 69	■	≡	X	V	0	14	Water
70 - 79	■	≡	X	V	0	14	
80 - 89	■	≡	Z	N		11	
90 - 99	■	≡	Z	N		11	
100 - 109	■	≡	X	F		10	
110 - 119	■	≡	X	F		10	
120 - 129	■	≡	X	F		10	Pine forest
130 - 139	⊕	I	=			8	
140 - 149	⊕	I	=			8	
150 - 159	⊕	I	=			8	
160 - 169	⊕	:	-			6	
170 - 179	:	:	.			5	
180 - 189	:	.				2	Beach
190 - 199	:	.				2	Arcade forest
							Forest agri-cultural complex

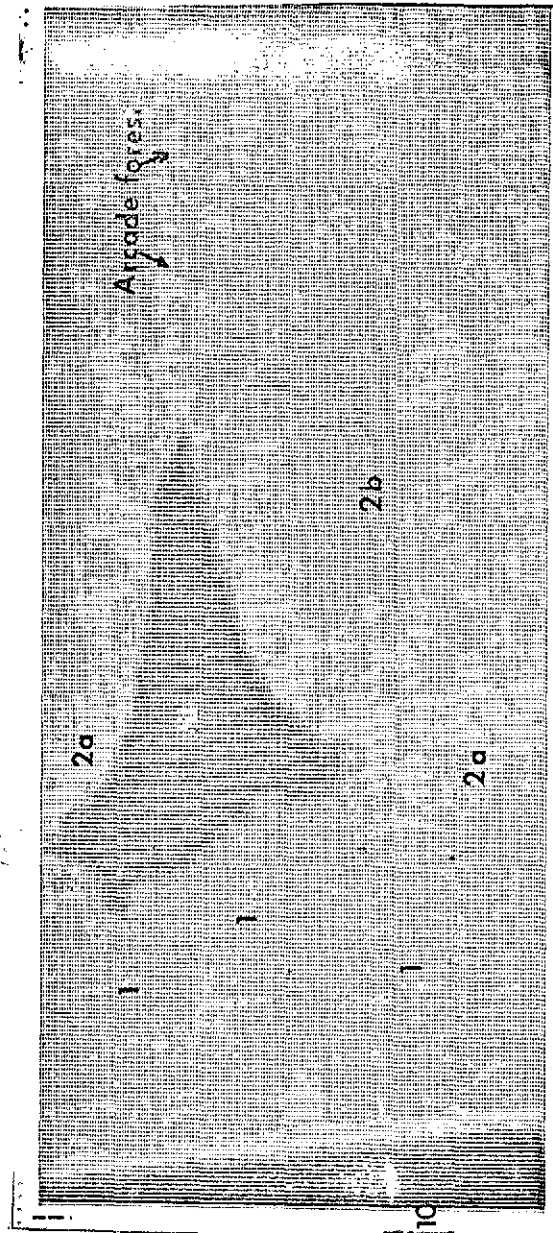


Figure 3 : Printout of the Born region MSS 7

- 1 : Pine forest
- 2a : Forest agricultural complex
- 2b : Forestry complex
- 10 : Water = Ponds-Ocean
- Arcade forest

The symbol 8 does not correspond to any particular landscape. It marks on the printout, boundaries of very contrasted zones.

2 - The Cocumontais region

The Mas d'Agenais forest (zone n° 7) surrounded by agriculture (zone n° 6), mainly makes up of deciduous trees is easily located on the display of MSS 5 image (figure 4).

Three gray levels can be brought out on the display of the forest. Now if the floristic composition of the forest is well known, it is not the case of the repartition of principal species which needs and actual notions of ground truth.

The three gray levels are defined by physionomic criteria, and no floristic criterium is used. These levels correspond to : clearing (symbols n° 9 and 6) and arborescent state (symbol n° 14).

CODING TABLE : MSS 5

125 - 129	■	≡	X	V	0	14	Shadows of clouds
130 - 134	■	≡	X	V	0	14	
135 - 139	■	≡	X	V	0	14	
140 - 144	■	≡	X	V	0	14	
145 - 149	■	≡	X	V	0	14	Arborescent state
150 - 154	■	X	h			9	
155 - 159	■	;	-			6	Clearing
160 - 164	■	.	.			3	
165 - 169	■	.	.			2	Agriculture

Forest

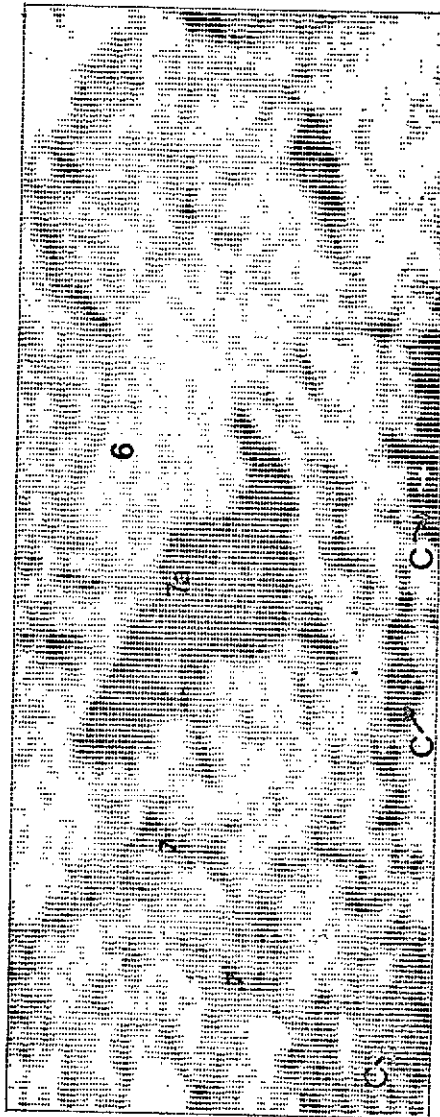


Figure 4 : Printout of the Documentais region
MSS 5

- 6 : Agriculture complex
- 7 : Deciduous forest
- 7a : The Mas d'Agenais forest
- C : Shadow of clouds.

3 - The Arcachon Basin

The information from the multispectral scanner images of September 25, 1972 is collected about 1 hour before the equinoctial low tide (coefficient 110). Most of the area uncovered by the Basin is dry. The water appears only in isolated channels of the Basin and lays bare sand and mud banks from 60 cm and 2 m above sea level.

The oyster beds and fisheries of Audenge-Lanton, situated to the east of the Basin can be distinguished. The southern part of the Basin is somewhat hidden by the shadow of a cloud.

The repartition of features of the Basin : channels, sand-banks, island, is well materialized in the display of data obtained from MSS 7 image (figure 5). Furthermore the display gives information on the sand-bank morphology.

The sand-bank which are the first emerged, are represented by the symbol n° 6 (A-figure 5), other sand-banks by symbol n° 8 (B-figure 5) and island by symbol n° 5 (C-figure 5).

CODING TABLE : MSS 7

60 - 69	☐	≡	X	V	0	14	Ocean and channels
70 - 79	■	≡	X	V	0	14	
80 - 89	▨	≡	Z	N		11	
90 - 99	▩	≡	Z	N		11	
100 - 109	▧	≡	X	F		10	
110 - 119	▦	≡	X	F		10	Others sand-banks
120 - 129	▥	≡	X	F		10	
130 - 139	⊕	I	=			8	
140 - 149	⊗	I	=			8	Sand-banks the first emerged
150 - 159	⊙	I	=			8	
160 - 169	⊛	;	-			6	
170 - 179	⋮	;	.			5	Island
180 - 189	⋮	.				2	
190 - 199	⋮	.				2	

A finer slicing of the optical density range between 130 and 179 should permit a trace level contours. It is particularly interesting in the case of Arcachon Basin, where sand strips are unstable, especially those sand strips at the mouth of the Arcachon basin.

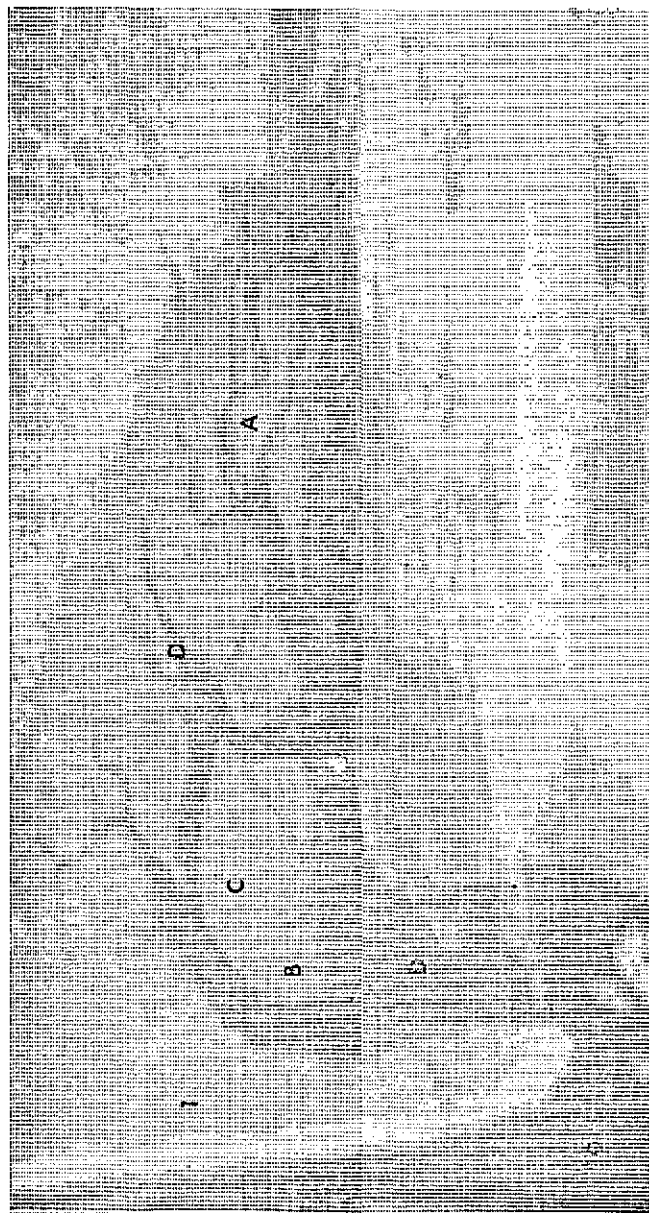


Figure 5 : Printout of Arcachon Basin MSS 7

- 1 : Pine forest
- 10 : Water
- A : Sand-banks the first emerged
- B : Others sand-banks
- C : Island
- D : Channels

III. ISSUE

This present study correspond to the first work of the ERTS-1 data processing operations. This work permits to describe ERTS-1 image and to select characteristic zones which are according to the studied images, either landscapes (Landes of Gascony) or homogeneous clusterings of vegetal species (cf. Val d'Aran). In the second part, quantitative analysis of selected sites represents only a little part of the informatical processing. Indeed, only displays of selected sites are carried out, describing selected landscapes on MSS imagery.

Chapter 3.

DISPLAY PROBLEMS

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In order to compare results with ground truth or biological truth, a restitution of the image is required.

This restitution can be made in several ways using a printer :

- in graphic symbols giving the same visual pattern as that produced by the original,
- in numerical values corresponding to the optical densities of each point.

The restitution can be applied to the image as a whole or to preselected zones. Various programs written in FORTRAN and machine language are necessary for the extraction and transformation of microdensitometer information stored on magnetic tape.

I. DATA CALCULATION AND TRANSFORMATION

I.1. Information decoding :

A program written in machine language takes the information stored in the buffer which is transmitted in FORTRAN and decodes the CP words in bytes : 15 bytes per 2 CP words. The optical density of all points in one row of the zone treated is thus stored in a table.

The decoding starts at the beginning of the file corresponding to the image or at a word defined in advance by its position, i.e., the row and column, centered on the axes of the digitized image.

The beginning decoding word is defined by :

$$MOTD = \frac{(\text{first column}-1)}{15} \times 2$$

Likewise, the number of words to be decoded is :

$$MOTF = \frac{(\text{last column}-1)}{15} \times 2 + 1$$

I.2. Calculating the optical density integrated on an elementary surface :

The numerized image can be reconstructed point by point or by elementary surfaces, in which case, the numerical output value is the optical density averaged over all the points of the elementary surface.

ELEMENT DE SURFACE
4
RRRR
RRRR
RRRR
4RRRR

K_C and K_L are the contraction coefficients of column and row, and d_{ij} is the optical density of point P_{ij} , the optical density of the elementary surface is :

Figure 1 : An example of an elementary surface.

$$K_C = 4 \quad K_L = 4$$

$$D = \frac{1}{K_C \times K_L} \sum_{i=1}^{K_L} \sum_{j=1}^{K_C} d_{ij}$$

The information is stored in a table and recorded on a disk.

I.3. Histogram calculation for optical density frequencies :

A histogram is presented in the form of a trace in which the different levels representing optical densities are placed on the abscissa, and the number of points having the same optical density is placed on the ordinate.

A FORTRAN program accumulates all points from the zone under study which have the same optical density and arranges them in a table which will then be translated into a x - y graph.

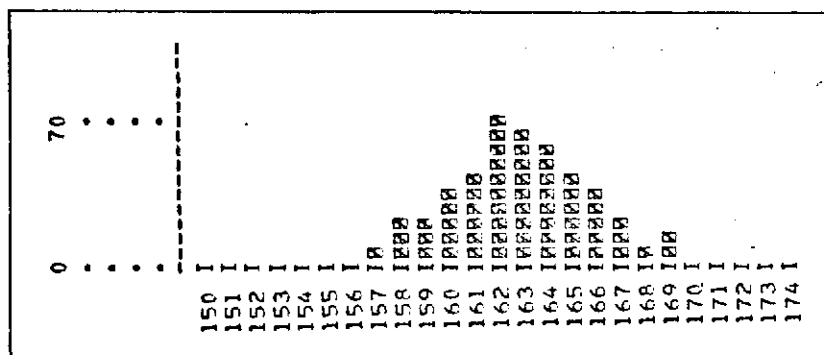


Figure 2 : Example of a histogram.

I.4. Calculation of statistical features

A statistical study is made for each surface corresponding to N measurement points. The statistical features of this population of N points provide useful information for identifying classes or for verifying the homogeneity of a class.

- Distribution average : given a population of N points whose optical density, x_i , is measured, and each value x_i coming out n_i times, the arithmetical average of the values measured is written :

$$\bar{x} = \frac{\sum n_i x_i}{N} = \sum \frac{n_i}{N} x_i = \sum f_i x_i$$

where f_i is the relative frequency of x_i .

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- Distribution variance :

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^K f_i (x_i - \bar{x})^2 \quad \text{where } K \text{ is the number of classes}$$

$$\sigma^2 = \frac{1}{N-1} \sum_{i=1}^K f_i (x_i - \bar{x})^2$$

- Standard deviation : σ

II. DATA RESTITUTION

II.1. Numerical output :

Stored numerical values can be printed out either systematically by aligning the values of each row in the zone on the output listing, or geographically by lining up points.

Figure 3 shows an example of the numerical output of a zone of 13 rows and 8 columns.

1387		1394	
↓		↓	
↓		↓	
↓		↓	
	8		
↓		↓	
1514-----[]	
[*****]			
[*****]			
13-----[]	
[*****]			
[*****]			
[*****]			
1526-----[]	

Figure 3

II.2. Display

The printout consists of a restitution of the image using the graphic symbols available on a printer.

To insure an accurate image a correction of the distortion on the output image must be made. A character is inscribed within a $1/10 \times 1/6$ - inch rectangle, thus straightening out the image by means of a row and column contraction equal to : $K_C/K_L = 6/10$.

Each optical density level is represented by a graphic symbol. With adequate grouping, the total number of optical density levels (256) reduced, according to the number of populations to be identified on the photographic sample under study. 14 combinations of symbols are used.

■	≡	X	V	O	14
■	≡	W	X	O	13
■	≡	W	Z	M	12
■	≡	Z	N		11
■	≡	X	F		10
%	%	X			9
≡	=	I			8
+	-	I			7
+	:	:			6
:	:	.			5
:	:				4
:	:				3
.	.				2

Figure 4 : Table of the graphic symbols used : the symbols are represented by numbers 1 to 14 (1 = white) and are the results of overprinting 1, 2, 3, or 4 characters.

The coding scale can be chosen arbitrarily, but generally the choice is made so that the shading is as close as possible to the original image.

TABLE DE CODAGE									
140 - 143	■	=	X	V	O	14			
144 - 147	■	=	X	V	O	14			
148 - 151	■	=	X	V	O	14			
152 - 155	■	=	X	V	O	14			
156 - 159	■	=	X	V	O	14			
160 - 163	■	=	1			8			
164 - 167	■	=	1			8			
168 - 171	■	=	1			8			
172 - 175	■	=	1			8			
176 - 179	.	.				2			
180 - 183	.	.				2			
184 - 187	.	.				2			
188 - 191	.	.				2			

Figure 5 a

Figure 5 b

Example of a coding table (figure 5 a) showing 3 classes of points which are then printed out.

In addition, with a selective printout one class of points can be made to stand out from all the other classes (figure 6).

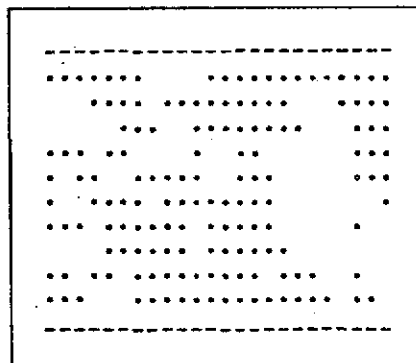


Figure 6 : Example of a selective printout.

III. EXAMPLES OF RESULTS

III.1. Treatment of a photograph taken from a sounding balloon.

The image treated was taken during the flight of a sounding balloon at an altitude of about 40 km, during a CNES mission in March, 1971, and shows the Toulouse area, specifically the Bouconne forest surrounded by cultivated land (figure 7).

Treatment by the color equidensity method developed by the Service de la Carte de la Végétation shows the three types of vegetation in the forest.

Zone 1 : area reforested in maritime pine.

Zone 2 : deciduous trees, oaks and hornbeams.

Zone 3 : zone of oaks recently cut.

The digitization of the image followed by an integral printout shows these three classes of vegetation (figure 8), while the selective display shows only one class (figures 9, 10, and 11).



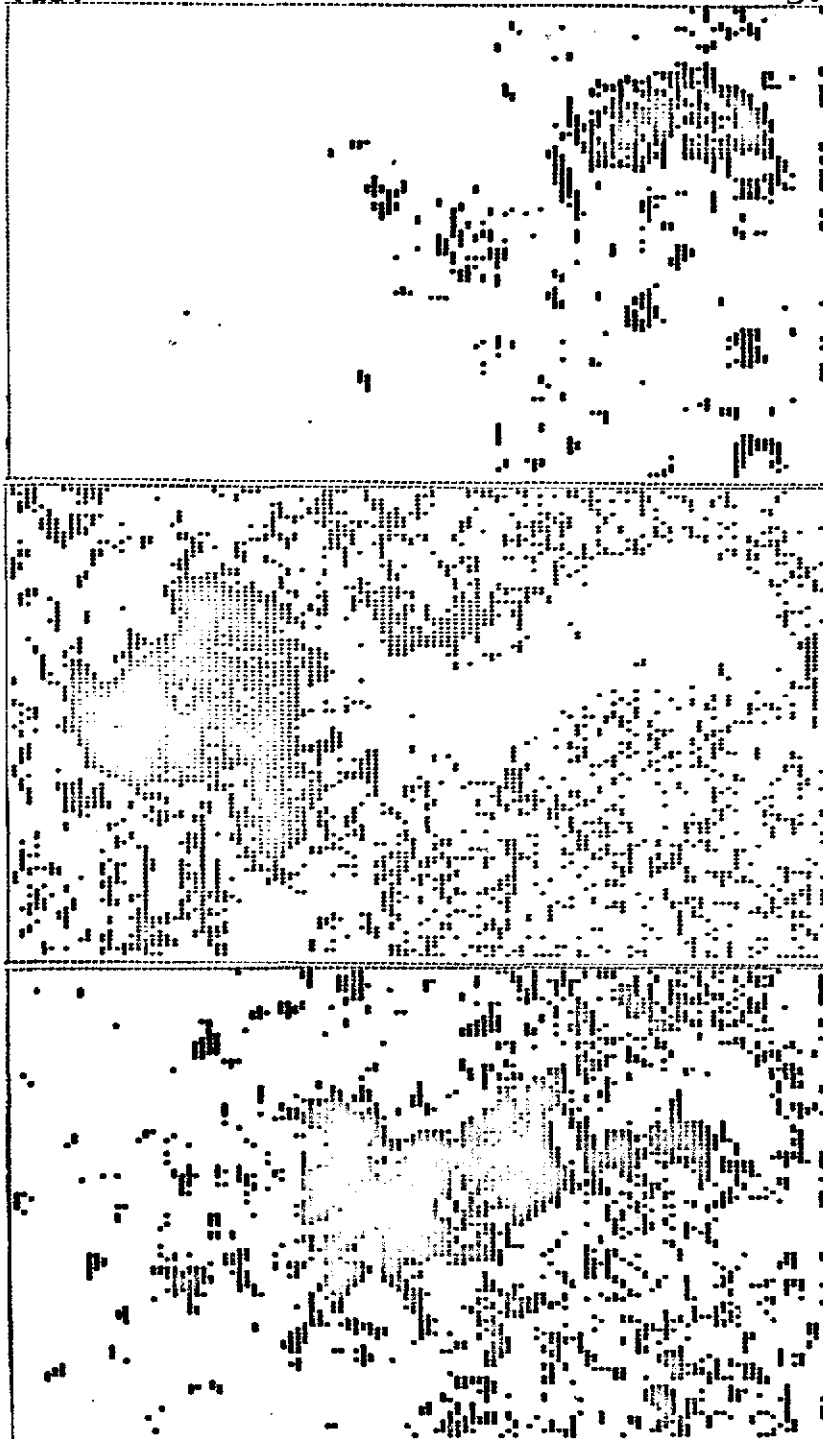
Figure 7
Photo of Bouconne Forest,
taken by a sounding balloon



Figure 8
Printout of a digitized
image of Boucenne Forest.

(11)

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Figures 9, 10, 11 : Selective display isolating
Zones 1, 2, 3.

III.2. Treatment of a photograph taken from the ERTS A satellite :

This example of applying the methods developed is part of the ARNICA program. The photographs treated are furnished by the ERTS A satellite, which flies above the earth at an altitude of approximately 900 km.

The test zone was chosen in a geographical setting in which the distribution of natural resources is already known.

Figure 12 shows the photograph taken by ERTS in the area of the Aran Valley in a visible spectral band ($0,6-0,7\mu$). The forests, particularly fir, are shown as on the Vegetation Map (figure 13).

The digitized image, treated using the study of homogeneous samples of soil occupation types, especially for the 3 predominant classes of vegetation in the zone, i.e., firs, pines, and moors, exhibits agreement with ground truth (figure 14). On the reconstituted image, the firs are shown in dark gray, pines in medium gray, and moors in light gray.

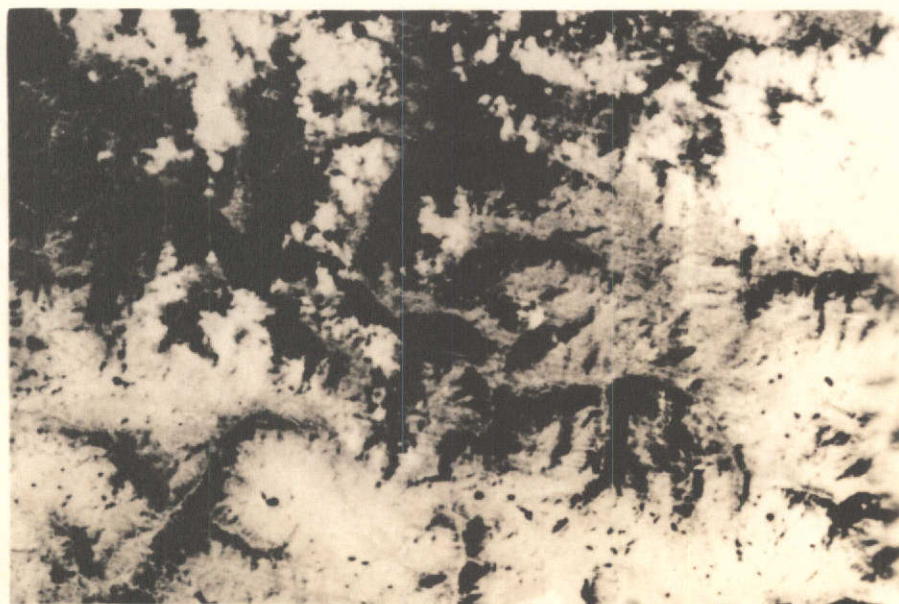


Figure 12 : Part of an ERTS photograph (MSS 5)



Figure 13 : Test zone on the Vegetation Map



Figure 14 : Numerized map of the test zone. Each symbol represents an 80 x 80 meter area. Firs are shown in dark gray, pines in medium gray, and moors in light gray.

Chapter 4.

METHOD FOR LOCATING SAMPLES
ON ERTS IMAGERY

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I. SCIENTIFIC JUSTIFICATION

When digitizing the ERTS imagery using the Scandig (Joyce Loeb) microdensitometer, it is impossible to line up the digitalization axes (sweep lines and columns formed by each digitalization step) systematically with the image's reference axes, which are defined by a system of 4 crosses.

In order to locate the same samples in a set of 4 ERTS photographs taken simultaneously with the Multispectral scanner (bands MSS 4, MSS 5, MSS 6, MSS 7), it is necessary to define the reference system on each photograph.

II. METHOD

II.1. Locating crosses

First, the crosses on the photograph must be located automatically. The points making up these crosses do not give a specific response, since their optical density range differs from one digitized to another, thereby making an automatic referencing of crosses valid for a whole set of imagery impossible.

Figure 1 shows a printout of a white cross on a black background from an ERTS photographic negative imagery with a 25μ step. The width of the features is approximately $4 \times 25\mu = 0,1$ mm. Thus, when the digitalization step is between 50 and 100μ , the integration effect makes the optical response of the cross indiscernible.

Figure 2 gives the corresponding numerical printout. The optical responses of points forming the cross are included in the range 171-189, while the surrounding points give an optical response of over 190.

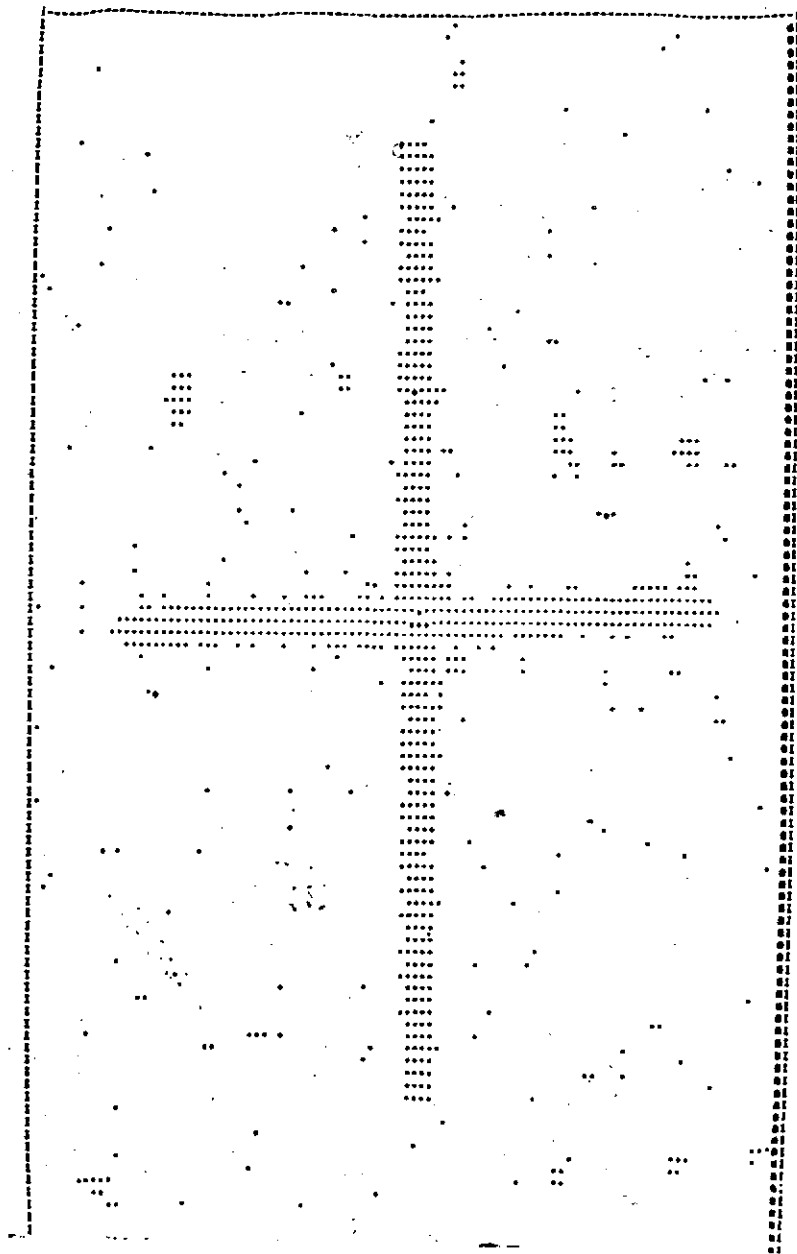


Figure 1

Printout of a cross on ERTS image

ARNICA II - 2

In order to obtain specific optical density values which could help locate the center of the crosses on all the ERTS photographs, a pinhole is manually pierced in the center of each cross. After digitalization this hole appears as a closed structure with a minimal optical response.

• Definition of the optical density threshold indicating a hole :

The optical density threshold for a hole made in an image is determined by a numerical printout (figure 3). The visual responses are 1, 2, or 3. The transparent part of the photograph gives an optical density between 15 and 40, whereas the range from 0-10 indicates a hole in the photograph.

• Barycenter of a hole :

The diameter of the hole must be more than 4 times the size of the digitalization step in order to avoid integration effects at each step ; i.e., for a maximum step of 100μ , the diameter must be 0,4 mm.

A FORTRAN subroutine determines the barycenter of all closed structures corresponding to an optical density of less than 10, regardless of structural form.

Figure 4 shows a printout of a hole in the center of a cross. Figures 5 (a, b and c) show several possible shapes for holes :

Figure 5a : fairly even hole with a diameter of about $10 \times 25\mu = 0,25$ mm.

Figure 5b : hole whose edges are partially covered by fragments of film.

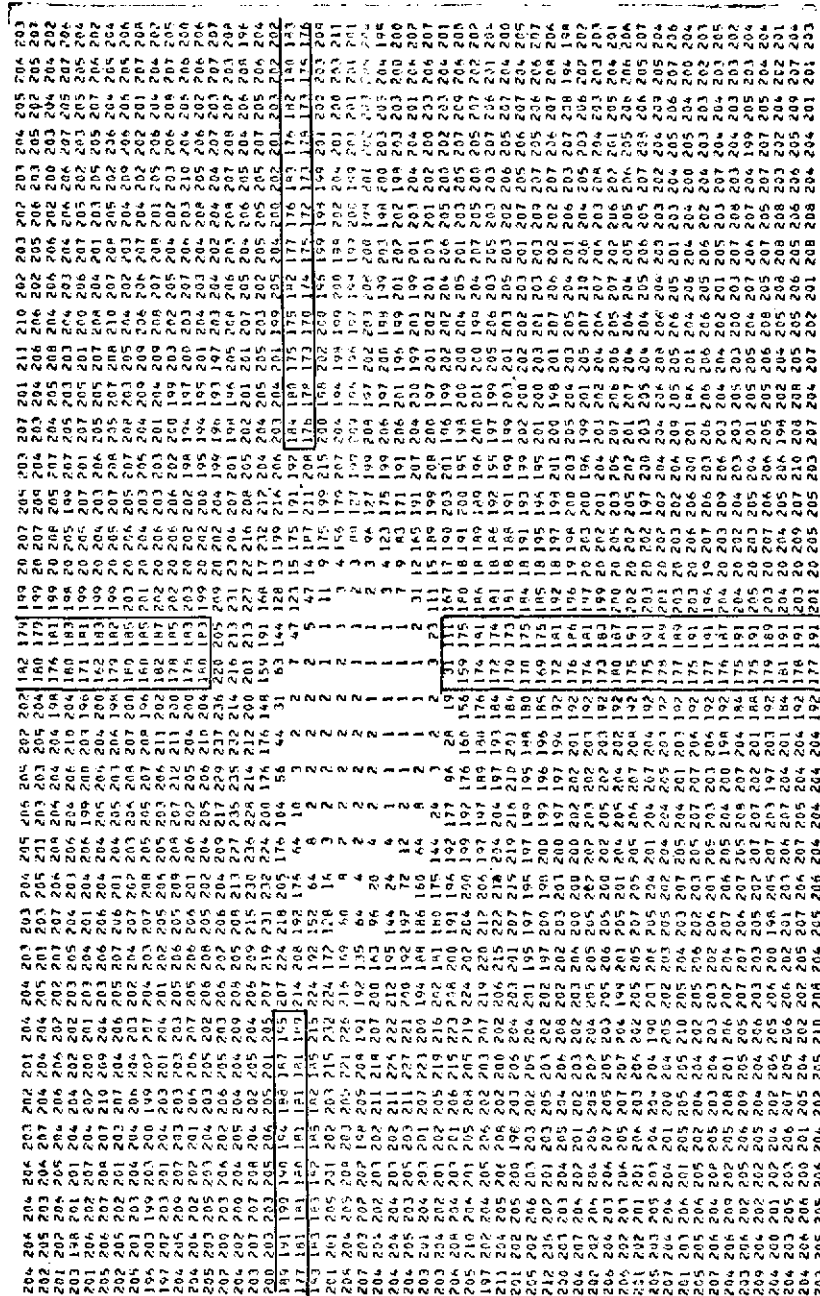


Figure 3

Numerical printout of a pinhole
at the center of a cross.

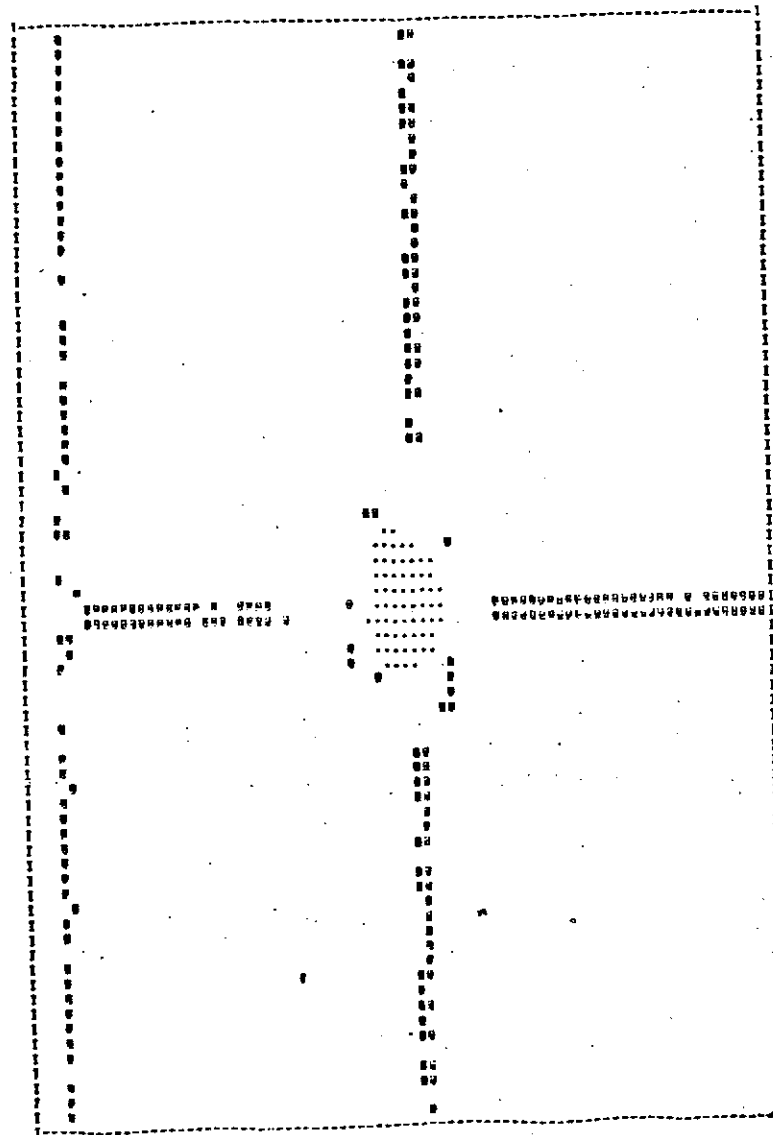


Figure 4
Printout of a pinhole
at the center of a cross.

(8)

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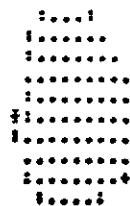


Figure 5 a

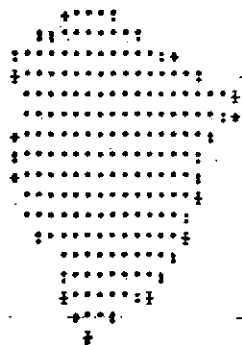


Figure 5 b *

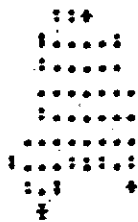


Figure 5 c

Possible shapes for holes

Figure 5c : uneven hole with a diameter
 $7 \times 25\mu = 0.175 \text{ mm.}$

. Search Algorithm

The search is done systematically, row by row following the microdensitometer's sweep on the photograph. Each closed structure with an optical density below 10 is tabulated. At the end of the sweep the structures with definite barycenters are thus determined. A first test checks the orthogonality of each system formed by a combination of 3 barycenters, so that any accidental holes in the photograph can be eliminated. An additional test verifying the distance between each pair of barycenters (the crosses are 58 and 60 mm apart on the ERTS photographs) determines the position of the set of 3 crosses.

II.2. Transposing the referencing system

A sample defined in the referencing system formed by the crosses on the ERTS photograph can be identified in the system of digitalization axes by a translation followed by a rotation of the system of axes.

The problem involves replacing x-y coordinates (centered at 0) (figure 6) by column and row coordinates centered at ω , where ω is the starting point for the digitalization located either inside or outside the photograph.

In figure 6 a coordinate ωC_1 is calculated as follows :

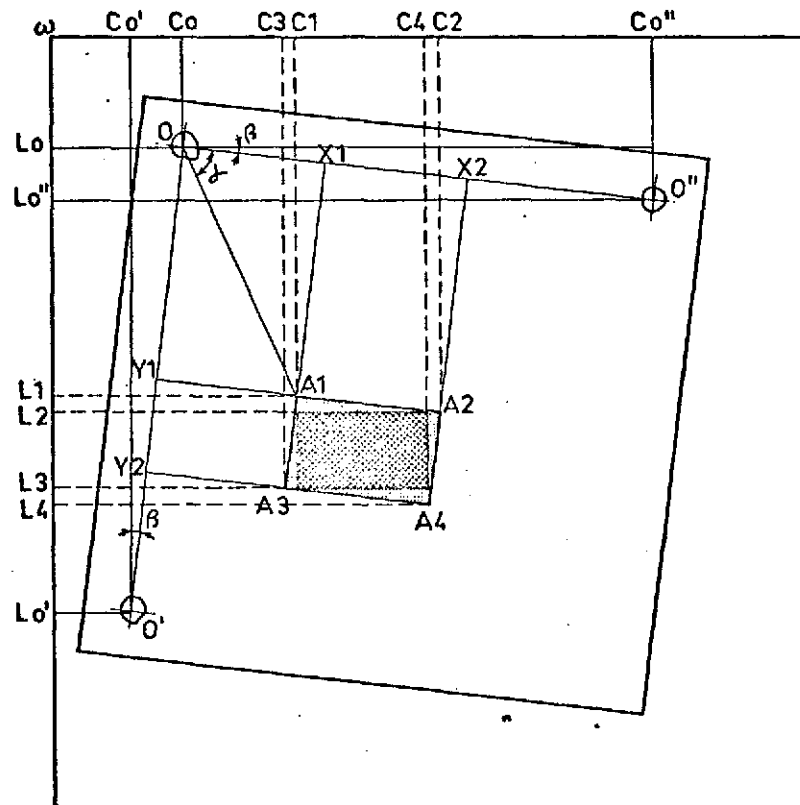


Figure 6

Transposing of referencing system :

The pinholes on ERTS image are materialized by features at points O, O', O''. The external framework represents the digitalization axes.

$$\begin{aligned}
\overline{\omega C_1} &= \overline{\omega C_0} + \overline{C_0 C_1} \\
&= \overline{\omega C_0} + \overline{OA_1} \times \cos(\alpha + \beta) \\
&= \overline{\omega C_0} + \overline{OA_1} \times \cos\left(\operatorname{artg} \frac{\overline{C_0 C_0''}}{\overline{L_0 L_0''}} + \operatorname{artg} \frac{\overline{OY_1}}{\overline{OX_1}}\right) \\
&= \overline{\omega C_0} + \left| \sqrt{\overline{OX_1^2} + \overline{OY_1^2}} \right| \times \cos\left(\operatorname{artg} \frac{\overline{C_0 C_0''}}{\overline{L_0 L_0''}} + \operatorname{artg} \frac{\overline{OY_1}}{\overline{OX_1}}\right)
\end{aligned}$$

Where $\overline{\omega C_0}$, $\overline{C_0 C_0''}$, $\overline{L_0 L_0''}$ are known by means of the pinhole reference.

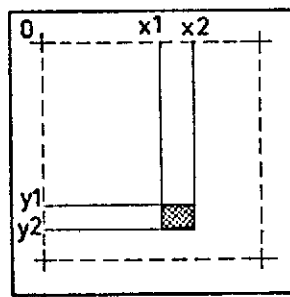
Only the central values of $\omega C_1, \omega C_2, \omega C_3, \omega C_4$, and $\omega L_1, \omega L_2, \omega L_3, \omega L_4$, are kept to identify the rectangle inscribed in the sample. This "new" sample is slightly smaller than the original sample. In practice, angle β between the two reference systems can be reduced to less than 1° by careful framing of the image on the drum of the microdensitometer, so that the loss of information is negligible.

III. RESULTS

Holes are made in the center of 3 crosses, using a needle under a microscope. Possible errors in this procedure stem from the non-standardization of the size and shape of the holes and from problems in locating the exact center of the crosses. An error of $1/10$ mm causes a shift of 4 rows or columns for a photograph digitized at 25μ .

In the future, a better perforation process will be used (laser, microperforator ...) in order to make the best possible use of automatic referencing on a digitized photograph.

Figures 8, 9, 10 and 11 illustrate the results of the above procedure. A test site in the Aran Valley was located in this way on 4 ERTS images taken on August 19, 1972.



The test-site is an area defined by lining up reference crosses on a set of photographs :

$X_1 = 25,85 \text{ mm}$
 $X_2 = 29,02 \text{ mm}$
 $Y_1 = 35,91 \text{ mm}$
 $Y_2 = 39,01 \text{ mm}$

Figure 7

Figure 8 shows the printout of the site made from the photograph E-1027-10135-4-01, taken by the multispectral scanner, band MSS 4. Three optical density ranges were coded to represent 3 types of vegetation on the ground.

Figure 9, 10 and 11 show the same zone from photographs E-1027-10135-5-01 ; E-1027-10135-6-01 ; E-1027-10135-7-01 taken in multispectral scanner bands MSS 5, MSS 6, and MSS 7.

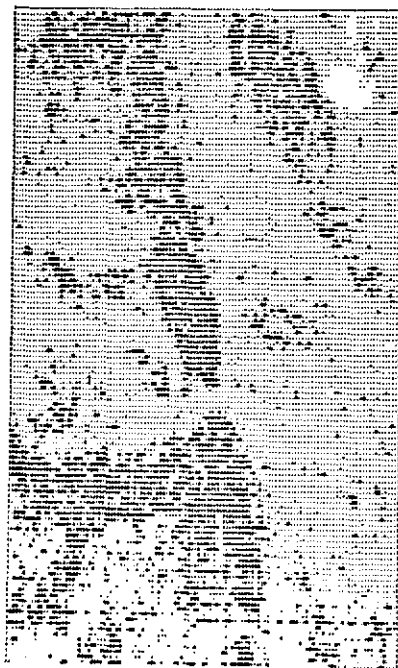


TABLE DE CODAGE

166 - 167	■ ■	X V 0	14
168 - 169	■ ■	X V 0	14
170 - 171	■ ■	X V 0	14
172 - 173	■ ■	X V 0	14
174 - 175	■ ■	X V 0	14
176 - 177	■ ■	X V 0	14
178 - 179	+ :	-	6
180 - 181	. .		2
182 - 183	. .		2
184 - 185	. .		2
186 - 187	. .		2
188 - 189	. .		2
190 - 191	. .		2
192 - 193	. .		2

Figure 8

Printout of the test-site from MSS 4 image
using a 3 ranges coding table.

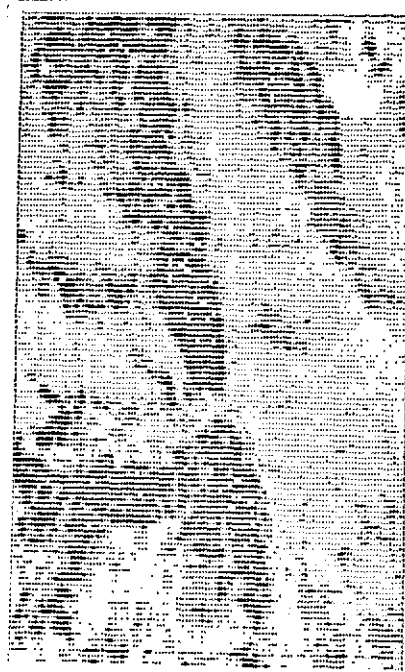


TABLE DE CODAGE

140 - 143	■ ■ ■ ■	X V O	14
144 - 147	■ ■ ■ ■	X V O	14
148 - 151	■ ■ ■ ■	X V O	14
152 - 155	■ ■ ■ ■	X V O	14
156 - 159	■ ■ ■ ■	X V O	14
160 - 163	+ + + +	-	6
164 - 167	+ + + +	-	6
168 - 171	+ + + +	-	6
172 - 175		2
176 - 179		2
180 - 183		2

Figure 9 : Printout of the test site from
MSS 5 image.

140 - 159 : Dark gray : Fir
160 - 171 : Medium gray : Pine
172 - 183 : Light gray : Moor

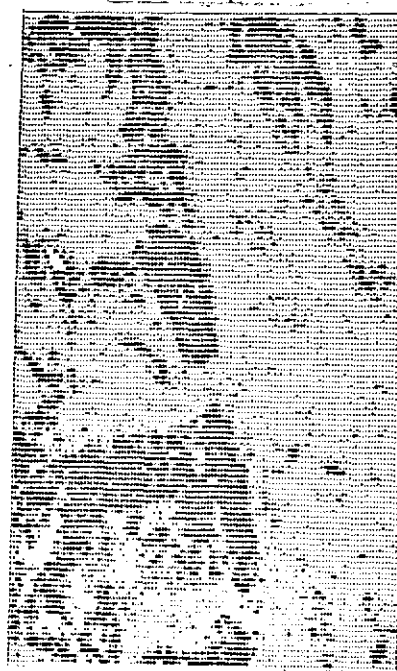


TABLE DE CODAGE

170 - 171	■ ■	X V 0	14
172 - 173	■ ■ ■	X V 0	14
174 - 175	■ ■ ■	X V 0	14
176 - 177	■ ■ ■	X V 0	14
178 - 179	■ ■ ■	X V 0	14
180 - 181	■ ■ ■	X V 0	14
182 - 183	■ ■ ■	X V 0	14
184 - 185	■ ■ ■	X V 0	14
186 - 187	♦ : -		6
188 - 189	♦ : -		6
190 - 191	. .		2
192 - 193	. .		2
194 - 195	. .		2
196 - 197	. .		2
198 - 199	. .		2
200 - 201	. .		2

Figure 10 : Printout of the test-site
from MSS 6 image.

170 - 185 : Dark gray : Fir
 186 - 189 : Medium gray : Pine
 190 - 201 : Light gray : Moor

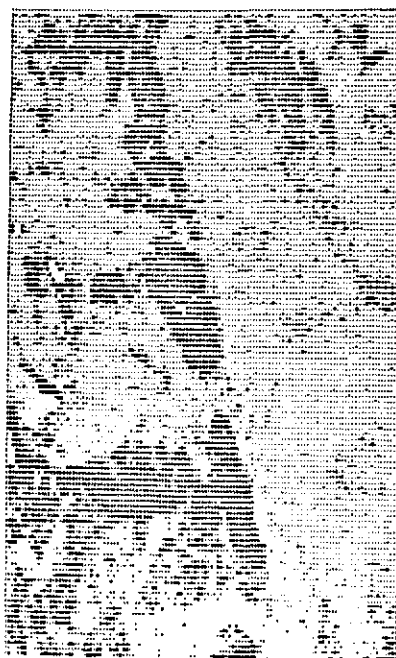


TABLE DE CODAGE

172 - 173	■ ■ ■	X V 0	14
174 - 175	■ ■ ■	X V 0	14
176 - 177	■ ■ ■	X V 0	14
178 - 179	■ ■ ■	X V 0	14
180 - 181	■ ■ ■	X V 0	14
182 - 183	■ ■ ■	X V 0	14
184 - 185	■ ■ ■	X V 0	14
186 - 187	■ ■ ■	X V 0	14
188 - 189	■ ■ ■	X V* 0	14
190 - 191	• • •	-	6
192 - 193	• • •	-	6
194 - 195	• • •		2
196 - 197	• • •		2
198 - 199	• • •		2
200 - 201	• • •		2

Figure 11 : Printout of the test-site
from MSS 7 image.

172 - 189 : Dark gray : Fir
 190 - 193 : Medium gray : Pine
 194 - 201 : Light gray : Moor

Chapter 5.

RESPONSES OF DIFFERENT TYPES
OF SOIL OCCUPATION DEFINED
FROM HOMOGENEOUS SAMPLES

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I. DETERMINING HOMOGENEOUS SAMPLES

In order to recognize structures on an image, one must first define characteristics of the well known homogeneous structures to be found on the image.

In the Aran Valley study, surfaces occupied by homogeneous vegetation types, called samples, are defined by the Service de la Carte de la Vegetation, aided by ERTS image, and the Vegetation Map of the corresponding zone.

The correspondence between the Vegetation Map of the Aran Valley zone and the ERTS image E-1027-10135-01 taken August 19, 1972, in the visible spectral band MSS 5, makes it possible to take samples on the ERTS image. Each sample is determined by its coordinates in mm, in the reference system found on each ERTS image, defined by 4 small crosses (Cf. Method for locating samples on ERTS Imagery).

The samples selected correspond to surfaces occupied by firs, pines and moors, which are the major types of vegetation in the region.

In this way, 14 samples were selected from the ERTS image. Figure 1 shows the vegetation map of the Aran Valley and the samples taken from the study sites, 1 to 14, well known by the Service de la Carte de la Vegetation. In Figure 2 the corresponding sub-test zone on the ERTS image is shown with the location of the test-sites.

A Fortran routine transforms these coordinates in mm through a rotation plus a translation into digital coordinates (Cf. Method for locating samples on ERTS Imagery).



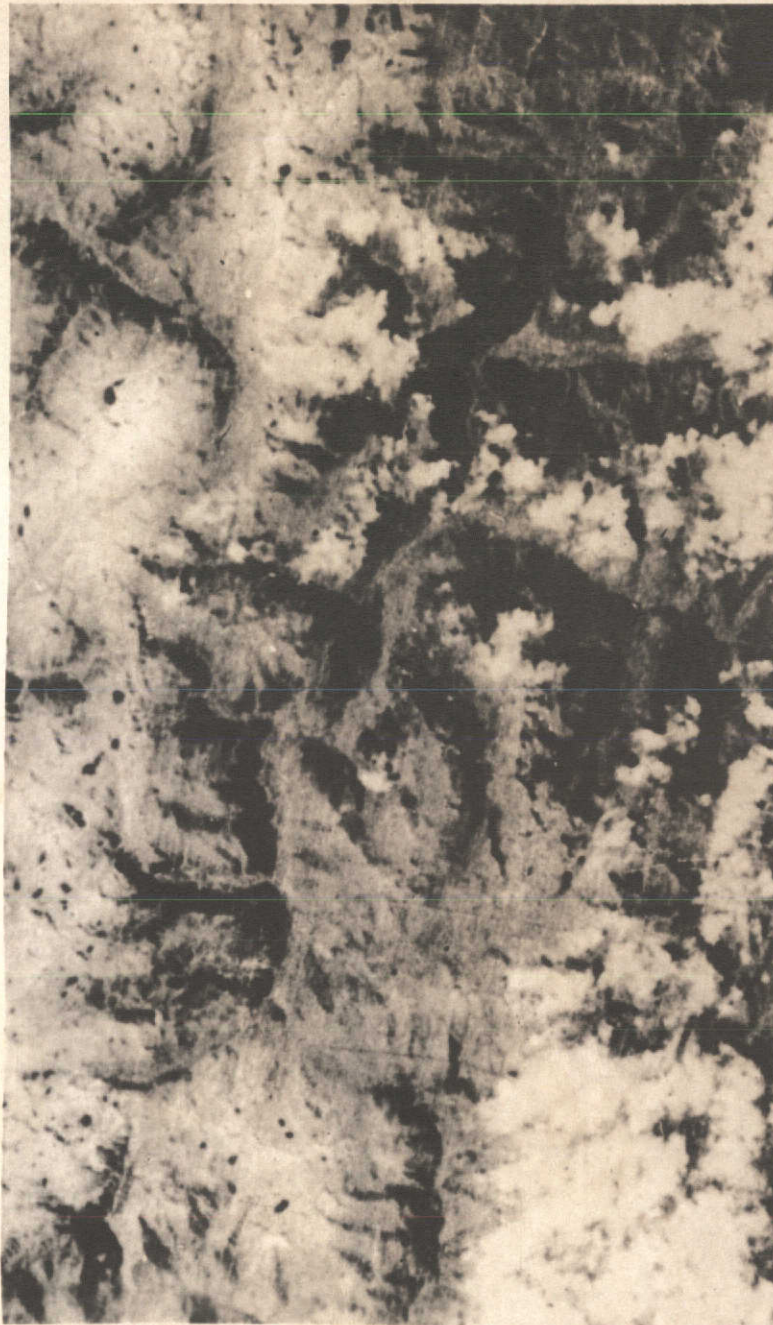


Figure 2

Part of ERTS image with samples location.

The preliminary study of these samples using the data restitution and treatment routine (Cf. Image Display Problem) gives the histograms of the optical responses in the MSS band 5 for fir, pine and moor classes of vegetation (Figure 3). It can be pointed out that there is a discrimination between optical density ranges characterizing each class of vegetation. The minimum and maximum values of each range correspond to the mean plus or minus the standard deviation. Using these optical density ranges one can choose a coding scale for the image printout of the test zone. Firs are shown by dark gray symbols, pines by medium gray, moorlands by light gray on Figure 4.

The position of fir forests is taken as reference mark for the selection of homogeneous areas occupied by pitch pines, high altitude grasslands, all of which are not large enough for identification on an original negative.

A total of 32 samples were chosen, the size of which varies from 40 to 200 digitized points. For a digitization step of 25μ , each point corresponds to an elementary surface of :

$$79 \text{ m} \times 79 \text{ m} \approx 6200 \text{ m}^2 = 0,62 \text{ ha}$$

on the ground. Thus, the samples represent land areas varying from :

$$\begin{aligned} 40 \times 0,62 \text{ ha} &= 24,8 \approx 25 \text{ ha to} \\ 200 \times 0,62 \text{ ha} &= 124 \text{ ha.} \end{aligned}$$

II. STUDY OF THE SAMPLES

A Fortran routine gives row and column coordinates of studied samples on MSS 4, MSS 6, MSS 7 images using coordinates on MSS 5.

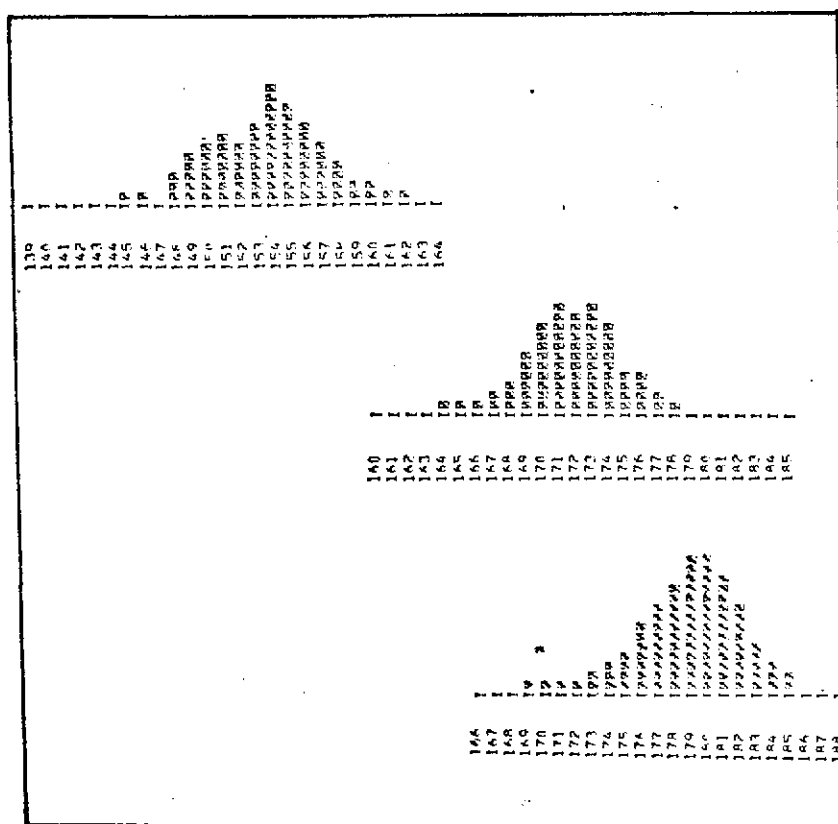


Figure 3
Histograms of MSS 5 responses of fir,
pine and moor classes

(7)

77

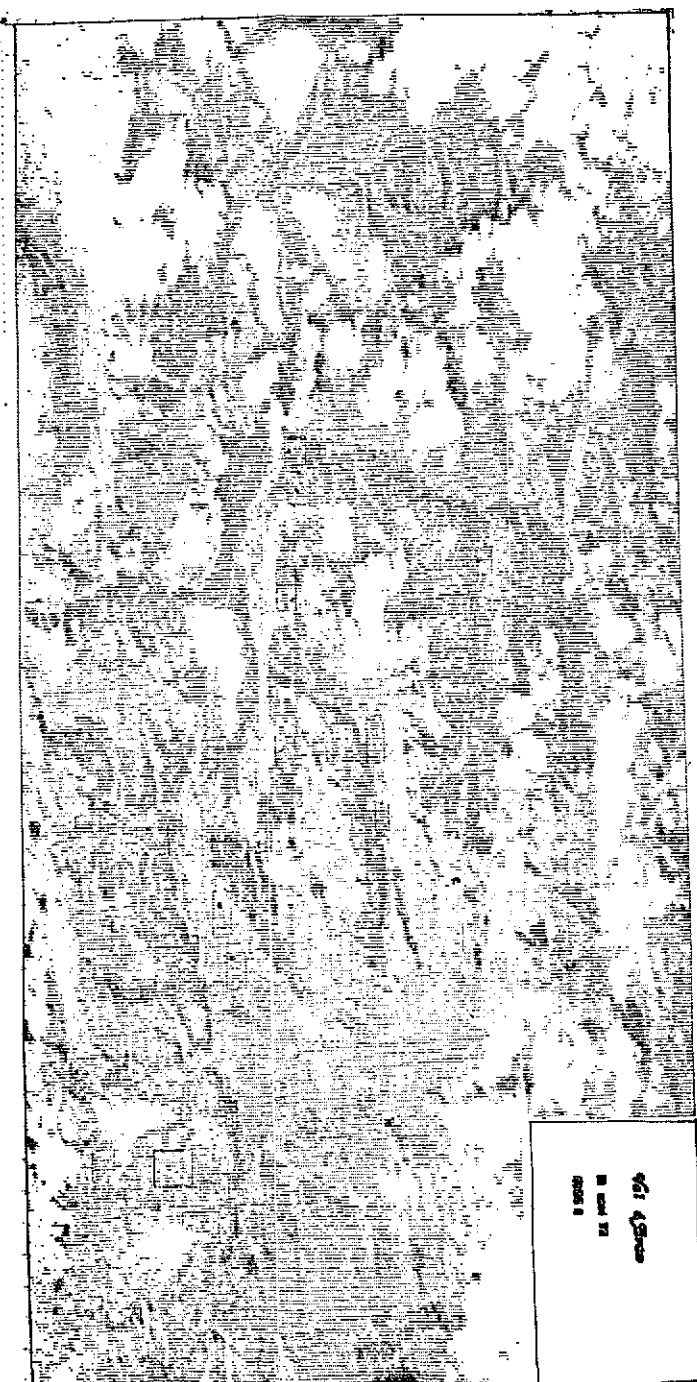


Figure 4
Printout of the Test-zone
part of digitized image

051

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The Fortran data processing routine can be used to obtain histograms of these samples in the 4 bands. The study of these distributions of points according to their optical density makes it possible to determine the homogeneity of samples.

Table (1) shows the characteristics of samples selected from the set of ERTS imagery (MSS 4, MSS 5, MSS 6, MSS 7). Each sample is characterized by the mean response and the standard deviation of the distribution.

Figure 5 gives the responses of classes : fir, pine, moor and grasslands in 4 spectral bands. The minimum and maximum values of the optical density range of each class of vegetation correspond to the mean plus or minus the standard deviation. It can be pointed out that fir class (sapins) can easily be distinguished from the others in band MSS 5.

Figure 6 shows the responses of these vegetation classes in bands MSS 5 and MSS 7. The graph shows the clustering of the responses of each class, particularly the separation of the fir response from the others. However, the two types of pine, sylvestre and pitch pine, as well as moors and grassland cannot be separated high mountain grasslands can however, be separated from moors and valley grasslands.

The separation of fir response can be seen in MSS 4 - MSS 7 graph (Figure 7). But the other vegetation cannot be distinguished from one another. Band MSS 6 gives results comparable to those of band MSS 7 but the separation between classes is less evident.

In conclusion, spectral bands MSS 5 and MSS 7 seem best for discriminating between classes of vegetation.

Table 1
Characteristics of samples in 4 MSS bands

TABLEAU MSS4 . MSS5 . MSS6 . MSS7									
Echantillons		MSS4		MSS5		MSS6		MSS7	
		Moyenne	Ecart type	Moyenne	Ecart type	Moyenne	Ecart type	Moyenne	Ecart type
Sapin	2	177.43	3.25	152.62	5.38	182.05	7.62	183.60	5.60
	3	179.5	3.35	156.30	7.24	181.77	6.45	185.5	6.55
	4	177	3.32	153.98	5.99	184.09	4.38	188.7	4.64
	6	176.5	3.64	155.73	9.78	182.99	6.45	185.52	6.20
	7	176.63	3.30	151.54	5.29	181.29	5.74	185.31	5.09
	8	177.44	3.55	153.71	9.02	185.33	5.70	189.81	5.88
	10	177.3	4.00	155.62	7.66	185.02	3.70	187.29	4.09
	12	178.52	3.62	159.52	9.57	187.12	6.16	192.28	5.53
	13	175.78	4.08	154.45	5.33	181.27	5.49	186.20	5.21
Pins sylvestres	14	182.78	3.07	171.43	4.44	187.65	3.15	193.69	3.63
	16	182.53	3.42	170.85	7.41	190.29	3.98	195.09	3.00
	17	181.96	3.94	163.92	4.70	189.62	5.11	193.29	7.00
Pins à crochets	21	181.43	4.04	169.66	6.24	190.66	4.05	193.80	4.41
	22	181.99	3.11	174.21	5.21	191.04	3.24	195.32	3.32
Landes	24	184.07	2.35	178.49	3.93	192.73	2.89	197.80	5.50
	26	183.73	2.85	178.52	4.56	192.08	3.28	196.10	2.84
Prairies	28	184.72	3.57	176.31	3.80	—	—	195.28	2.60
	31	185.18	2.78	178.44	3.89	—	—	198.24	2.87
Pelouses	32	185.03	4.84	181.42	4.66	—	—	193.58	5.12

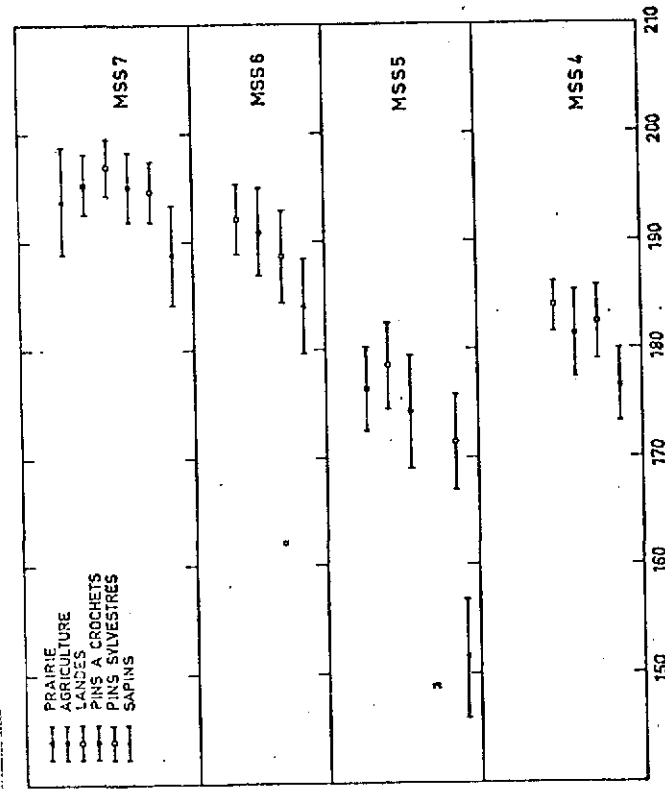


Figure 5

Optical density range of vegetation
classes in 4 MSS bands

- △— Grassland
- Agriculture
- Moors
- Pitch Pine : *Pinus uncinata*
- Sylvester Pine : *P. silvestris*
- ▲— *Abies pectinata*

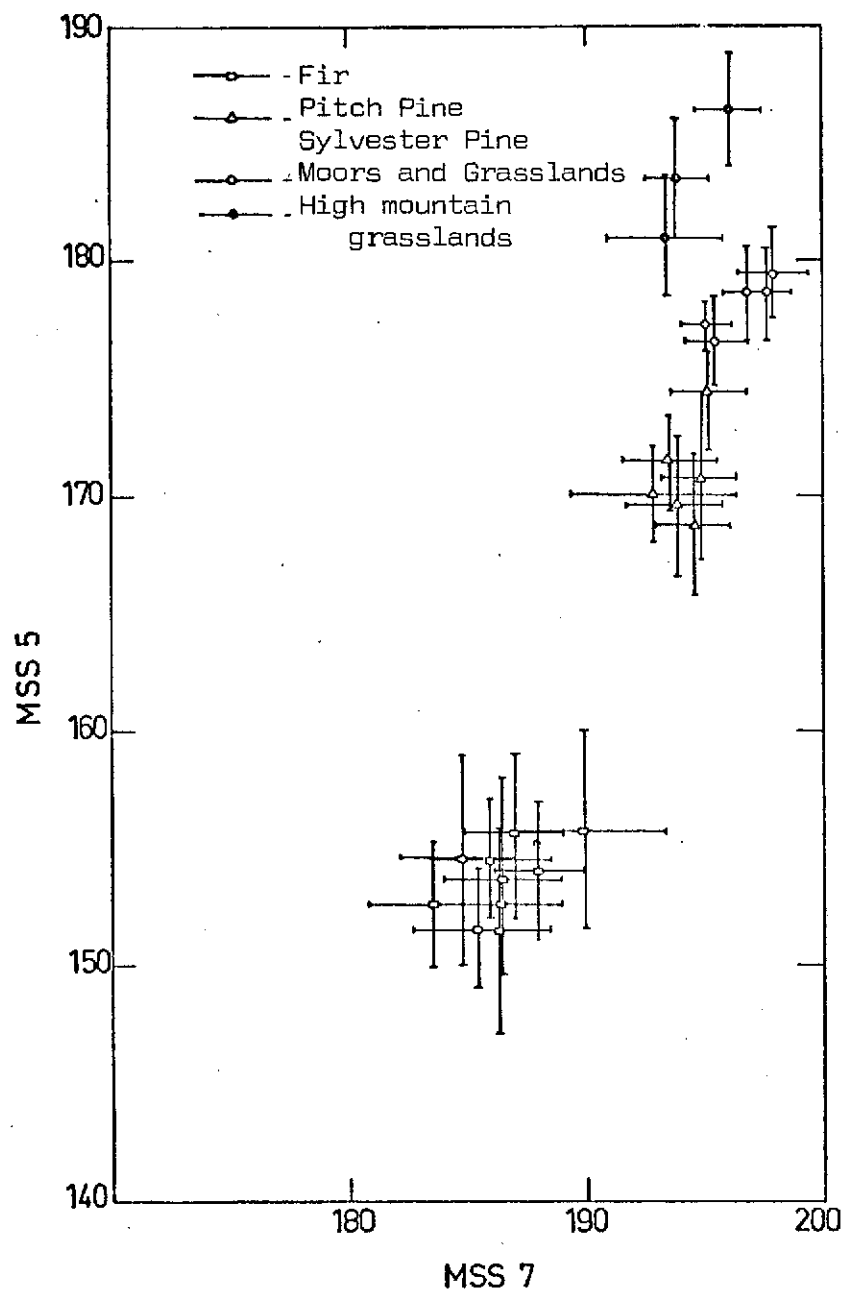


Figure 6

Responses of vegetation classes
in MSS 5, MSS 7 bands

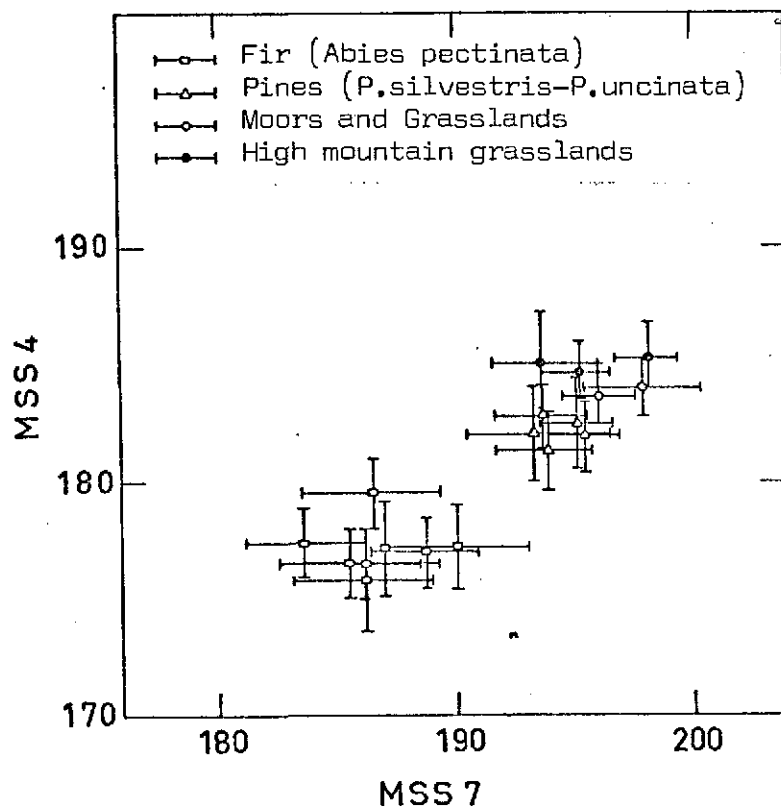


Figure 7
Responses of vegetation classes
in MSS 4, MSS 7 bands

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